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SPECIFICATIONS - DETAILED PROVISIONS
Section 16890 - Fiber Optic Cabling and Components

C O N T E N T S

SECTION 16890
FIBER OPTIC CABLING AND COMPONENTS

PART 1 - GENERAL

1.01 DESCRIPTION

A. Contractor shall furnish, install, test, and place into service fiber optic cabling and components as indicated on the Drawings and as specified herein.

B. Furnish and install auxiliary and accessory devices necessary for fiber optic communication system operation and to interface with equipment specified herein and in other Sections of these Specifications.

1.02 RELATED SECTIONS

A. The Contract Documents are a single integrated document, and as such all Specification Sections apply. It is the responsibility of the Contractor and its subcontractors to review all Sections and ensure a complete and coordinated project.

B. Related Specification Sections include, but are not limited to, the following:

1. Division 16 – Electrical

2. Division 17 – Instrumentation and Controls

1.03 REFERENCE STANDARDS AND CODES

All materials and equipment specified herein, including installation of same, shall conform to or exceed the applicable requirements of the following standards and codes (latest edition) to the extent that the provisions thereof are not in conflict with other provisions of these Specifications.

A. Telecommunications Industry Association/ Electronic Industry Association (TIA/EIA)

1. TIA/EIA-455-C: Standard Test Procedure for Fiber Optic Fibers, Cables, Transducers, Sensors, Connecting and Terminating Devices, and Other Fiber Optic Components

a. TIA/EIA-455-3 (FOTP-3): Procedure to Measure Temperature Cycling Effects on Optical Fiber, Optical Cable, and Other Passive Fiber Optic Components

b. TIA/EIA-455-25 (FOTP-25): Repeated Impact Testing of Fiber Optic Cables and Cable Assemblies,

c. TIA/EIA-455-33 (FOTP-33): Fiber Optic Cable Tensile Loading and Bending Test

d. TIA/EIA-455-37 (FOTP-37): Fiber Optic Cable Bend Test, Low and High Temperature

e. TIA/EIA-455-38 (FOTP-38): Measurement of Fiber Strain in Cables Under Tensile Load

f. TIA/EIA-455-41 (FOTP-41): Compressive Loading Resistance of Fiber Optic Cables,

g. TIA/EIA-455-82 (FOTP-82): Fluid Penetration Test for Fluid-Blocked Fiber Optic Cable

h. TIA/EIA-455-85 (FOTP-85): Fiber Optic Cable Twist Test

i. TIA/EIA-455-104 (FOTP-104): Fiber Optic Cable Cyclic Flexing Test

2. TIA-568-C.0: Generic Telecommunications Cabling for Customer Premises

3. TIA-568-C.1: Commercial Building Telecommunications Cabling Standard

4. TIA-568-C.3: Optical Fiber Cabling Components Standard

5. TIA-569-B: Commercial Building Standard for Telecommunications Pathways and Spaces

6. TIA-598: Color Coding of Fiber Optic Cables

7. TIA-607: Grounding and Bonding Requirements for Telecommunications in Commercial Buildings.

B. Other Standards

1. UL – Underwriters Laboratories

2. IEEE – Institute of Electrical and Electronics Engineers

3. NEMA – National Electrical Manufacturers Association

C. Codes

1. NFPA 70 – National Electrical Code (NEC)

1.04 SUBMITTALS

All submittals shall be in accordance with the General Conditions and requirements specified herein.

A. Shop Drawings

Contractor shall prepare and submit complete and organized information, drawings, and technical data for all material, equipment, and components. All drawings shall be legible and reduced to a maximum size of 11" x 17" for inclusion within the submittal. Shop drawings shall include, but not be limited to, the following:

1. Detailed Bill of Materials for all fiber optic cable, patch panels, connectors, fiber break-outs, splicing kits, splicing trays, innerduct, switches, cabinets, pull boxes, and appurtenances, listing: manufacturer's name, catalog/part number, quantity, size, and description.

2. Complete documentation for all fiber optic cable, patch panels, connectors, fiber break-outs, splicing kits, splicing trays, innerduct, switches, cabinets, pull boxes, cable lubricant, duct sealant, closures, identification markers, mounting hardware, and appurtenances, including: manufacturer's product literature, specifications, materials of construction, features and accessories, technical information, factory test reports, illustrations, and data in sufficient detail to demonstrate compliance with Specification requirements. Manufacturer’s literature and data shall be marked to clearly delineate all applicable information and crossing out all inapplicable information.

3. Installation requirements and procedures for fiber optic cables, patch panels, connectors, fiber break-outs, innerduct, and switches, including routing, splicing, and grounding requirements. Cable installation procedures shall clearly describe the steps to be taken to ensure that the fiber optic cables are not damaged during installation.

4. Fiber optic cable routing plan, patch panel location plan, and pull box plan. All information shall be shown on the same drawing, and shall be coordinated with the electrical conduit drawings. The plans shall show the location of all pull and mid-assist points, the direction of pull as applicable, calculated pulling tensions for each pull, and fiber optic cable manufacturer’s recommended maximum pulling tension for each type of fiber optic cable to be installed.

Contractor shall identify on the cable routing plan the location of each proposed cable splice. Fiber optic cable splices will only be permitted on a case-by-case basis, and only after the Contractor has demonstrated to the District's satisfaction, that fiber optic cable manufacturers are unable to manufacturer the specified cables in lengths that would allow installation without splices.

5. Layout and connection drawings for fiber optic patch panels.

6. A written field test procedure outlining the steps and methods that will be used to test the fiber optic cables during and after installation. Include a sample copy of the test form that will be used in the test procedure. Manufacture catalog data for the testing equipment to be utilized during the field testing procedures.

7. Fiber Optic Subcontractor qualification and experience information.

B. Project Closeout Submittals

1. As-built drawings of the fiber optic cable routing plan, patch panel location plan, and pull box plan showing all field changes.

2. Certified test results for each cable after installation stating the signal loss of each fiber in the cable between splices, across all splices, and from end to end after splicing and terminations are complete.

1.05 QUALITY ASSURANCE

A. To facilitate the District's future operation and maintenance, furnish material and equipment which is the product of one manufacturer to the maximum extent possible. Where this in not practical, all material and equipment of a given type shall be the product of one manufacturer.

B. As a minimum, product manufacturers shall be certified in accordance with ISO 9001.

1.06 FIBER OPTIC SUBCONTRACTOR

Contractor shall designate a Fiber Optic Subcontractor (FOS) to be responsible to furnish all labor, material, and equipment specified herein.

A. Qualifications

1. As a minimum, the FOS shall have been regularly engaged in the selection, purchase, installation, testing, and startup of fiber optic telecommunication systems on municipal water and wastewater projects.

2. FOS shall have been regularly engaged in performing coordination, selection of fiber optic materials and equipment to interface between programmable logic controllers, Supervisory Control and Data Acquisition (SCADA) systems, site access systems, and video surveillance systems, etc. for municipal water and wastewater projects of similar or larger magnitude for at least 3 years.

3. Contractor shall submit FOS qualifications, project references (5 minimum), and certifications for District review and approval.

4. Personnel employed for coordination, supervision, installation, testing, and startup shall be regularly employed and trained by the FOS. In addition, installation personnel shall be certified by the fiber optic cable manufacturer to install the selected fiber optic cable system.

B. Responsibilities

1. Select, coordinate, install, and test the fiber optic telecommunication system to provide proper operation and to interface with related equipment and materials furnished by other suppliers under other Sections of these Specifications, with existing facilities (where required), and with District provided Remote Telemetry Unit (RTU) equipment and/or SCADA system equipment.

2. Provide auxiliary and accessory devices necessary for system operation or performance and to interface with equipment provided by other suppliers under other Sections of these Specifications, with existing facilities (where required), and District provided RTU equipment and/or SCADA system equipment. These devices shall be provided whether they are shown on the Drawings or not, and shall be at no additional cost to the District.

3. Prior to installation of any conduit associated with fiber optic telecommunication system, the FOS shall verify conduit size, bends and routing with the Electrical Subcontractor and material suppliers for specific materials to be furnished, and notify the District of any conflicts or deviations.

4. Coordinate services of manufacturer's engineering representatives during installation and testing.

Contactor shall subcontract the work specified herein to a qualified FOS. All work performed is the responsibility of the Contractor even though references are made herein to work requirements and responsibilities of the FOS.

PART 2 - PRODUCT

2.01 FIBER OPTIC CABLING

A. All fiber optic cables shall be rated for use in indoor and outdoor applications, permitting cables to run from the outside plant environment to a building's cross-connection point without a transition at the building entrance.

B. Single-mode fiber optic cabling shall meet the following requirements:

Property	Specification
Construction	Loose Tube, Gel-Free, All Dielectric
Rating	Indoor/Outdoor, Riser-Rated Jacket, OFNR
Fiber Bundle Jacket Material	Medium Density Polyethylene
Number of Fibers Per Cable	xx (6, 12, 18, 24) as shown on Drawings
Nominal Fiber Core Diameter	8.3 microns
Nominal Cladding Diameter	125 microns
Wavelengths	1310 Nm / 1383 Nm / 1550 Nm
Maximum Attenuation	0.4 dB/km / 0.4 dB/km / 0.3 db/km
Min. Installation Bend Radius	7.6 inches
Min. Operation Bend Radius	5.1 inches
Max. Short-Term Tensile Load	600 pounds
Max. Long-Term Tensile Load	180 pounds

C. Multi-mode fiber optic cabling shall meet the following requirements:

Property	Specification
Construction	Loose Tube, Gel-Free, All Dielectric
Rating	Indoor/Outdoor, Riser-Rated Jacket, OFNR
Fiber Bundle Jacket Material	Medium Density Polyethylene
Number of Fibers Per Cable	xx (6, 12, 18, 24) as shown on Drawings
Nominal Fiber Core Diameter	62.5 microns
Nominal Cladding Diameter	125 microns
Wavelengths	850 Nm / 1300 Nm
Maximum Attenuation	3.4 dB/km / 1.0 dB/km
Min. Installation Bend Radius	7.6 inches
Min. Operation Bend Radius	5.1 inches
Max. Short-Term Tensile Load	600 pounds
Max. Long-Term Tensile Load	180 pounds

D. Temperature Range

The installation temperature range for the cable shall be from -10°C to +60°C. The operating temperature range for the cable shall be from -40°C to +70°C. Testing shall be in accordance with FOTP-3.

E. Tensile Loading and Fiber Strain

When tested in accordance with FOTP-33 and FOTP-38, a length of cable shall be tested to the rated tensile load. The rated tensile load shall be 2670 N (600 lb). While under the rated tensile load, the fiber shall not experience a measured fiber strain greater than 60% of the fiber proof test level. After being held at the residual load (30% of the rated tensile load) the fiber shall not experience a measured fiber strain greater than 20% of the fiber proof test level nor an attenuation change greater than 0.40 dB at 1550 Nm (single-mode) or greater than 0.60 dB at 1300 Nm (multi-mode). After the tensile load is removed, the fibers shall not experience an attenuation change greater than 0.40 dB at 1550 Nm (single-mode) or greater than 0.60 dB at 1300 Nm (multi-mode).

F. Compressive Loading Test

When tested in accordance with FOTP-41, the cable shall withstand a minimum compressive load of 220 N/cm (125 lb/in) applied uniformly over the length of the sample. The 220 N/cm (125 lb/in) load shall be applied at a rate of 2.5 mm (0.1 in) per minute. The load shall be maintained for a period of 1 minute. The load shall then be decreased to 110 N/cm (63 lb/in). Alternatively, the 220 N/cm (125 lb/in) load may be removed entirely and the 110 N/cm (63 lb/in) load shall be applied within five minutes at a rate of 2.5 mm (0.1 in) per minute. The 110 N/cm (63 lb/in) load shall be maintained for a period of 10 minutes. Attenuation measurements shall be performed before release of the 110 N/cm (63 lb/in) load. The change in attenuation shall not exceed 0.40 dB at 1550 Nm for single-mode fibers and 0.60 dB at 1300 Nm for multi-mode fiber.

G. Cyclic Flexing Test

When tested in accordance with FOTP-104, the cable shall withstand 25 mechanical flexing cycles at a rate of 30 ± 1 cycles per minute. The fiber shall not experience an attenuation change greater than 0.40 dB at 1550 Nm (single-mode) or greater than 0.60 dB at 1300 nm (multi-mode). No cracks, splits, tears or other opening shall be present on the inner or outer surface of the jacket. No visible cracks greater than 5 mm in the armor, if present, shall be present.

H. Twist Test

When tested in accordance with FOTP-85, a length of cable no greater than 2 meters will withstand 10 cycles of mechanical twisting. The fiber shall not experience an attenuation change greater than 0.40 dB at 1550 Nm (single-mode) or greater than 0.60 dB at 1300 Nm (multi-mode). No cracks or splits in the jacket shall be present when inspected under 5X magnification.

I. High and Low Temperature Bend

When tested in accordance with FOTP-37, the cable shall withstand four full turns around a mandrel at test temperatures of -10°C and +60°C. The fibers shall not experience an attenuation change greater than 0.40 dB at 1550 Nm (single-mode) or greater than 0.60 dB at 1300 nm (multi-mode).

J. Impact Resistance

When tested in accordance with FOTP-25, the cable shall withstand a minimum of 2 impact cycles at 3 locations separated by at least 150 mm. The impact energy shall be 4.4 Nm. The fibers shall not experience an attenuation change greater than 0.40 dB at 1550 nm (single-mode) or greater than 0.60 dB at 1300 Nm (multi-mode). The presence of visible cracks, splits, tears, or other openings on the outer surface of the jacket constitute a failure.

K. Temperature Cycling

When tested in accordance with FOTP-3, the change in attenuation after 2 cycles at extreme operational temperatures (-40°C to +70°C) shall not exceed 0.40 dB/km at 1550 Nm (single-mode) or 0.60 dB/km at 1300 Nm (multi-mode). The change in attenuation is measured with respect to the baseline values measured at room temperature before temperature cycling after the last low and last high temperature.

L. Water Penetration

When tested in accordance with FOTP-82, a one meter length of unaged cable shall withstand a one meter static head or equivalent continuous pressure of water for one hour without leakage through the open cable end.

M. Cold Impact Test

When tested in accordance with FOTP-25, the cable shall withstand a minimum of 2 impact cycles at 3 locations separated by at least 150 mm. The impact energy shall be 2.9 Nm. The cable shall be conditioned for at least 4 hours at the minimum installation temperature (-10°C). The presence of visible cracks on either the inner or outer surface of the jacket constitutes a failure. No optical measurements are required.

N. Optical fiber cables shall be FREEDM Loose Tube Gel-Free Cables as manufactured by Corning Optical Communications, or equal.

2.02 FIBER OPTIC PATCH PANELS

A. Provide a fiber optic patch panel at each fiber optic cable termination point. Patch panels shall accommodate all optical fibers in the cable.

B. Patch panel enclosures shall be rated NEMA 4X and shall be provided with hinged padlockable doors.

C. All fibers shall be connected and labeled in the patch panel.

D. Provide tight-buffered, riser rated patch cords with manufacturer installed connectors to connect the fibers from the fiber patch panels to switches or PLCs and to interconnect fibers within the patch panels.

E. Patch cords shall be Type Corning Cable Systems 505002K512000XM (X = length in meters), or equal.

F. Patch panels shall be Corning Cable Systems Model EDC-06P-NH, NEMA 4X enclosure with Corning Cable Systems CCH-CP12-15T closet connector housing panels, with SC adapters, or equal. Patch panel enclosures shall be lockable and equipped with quick release latch kits.

G. Fiber optic cables entering patch panels shall be provided with protection and strain relief via internal brackets, or a fan-out kit shall be provided at the end of each cable.

2.03 CONNECTORS

A. Fiber optic connectors shall be in accordance with EIA/TIA 568-B.3, and shall be in compliance with the Fiber Optic Connector Interchangeability Standard (FOCIS).

B. Unless specified otherwise, fiber optic connectors shall be field installable and SC compatible.

C. Fiber optic connectors shall meet the following requirements:

Property	**Specification**
Operating Temperature Range	-40 to 75°C
Technology	No-Epoxy, No-Polish
Ferrule Material	Ceramic
Housing Material	Composite
Nominal Fiber Outer Diameter	125 microns
Durability	≤ 0.2 dB change by 500 rematings
Jacketed Cable Tensile Strength	50 N, change ≤ 0.2 dB
900 µm Cable Tensile Strength	4.9 N, change ≤ 0.2 dB
Insertion Loss, Typical	0.1 dB (multimode), 0.2 dB (single-mode)
Insertion Loss, Maximum	0.5 dB

D. Fiber optic connectors shall be UniCam High Performance Connectors as manufactured by Corning Optical Communications, or equal.

2.04 ETHERNET SWITCHES

A. Where indicated on the Drawings, industrial Ethernet switches shall be provided to connect computers, PLCs, HMI units, etc. to the Plant Ethernet network. Unless specified otherwise, each Ethernet switch shall be provided with built-in fiber optic and copper Ethernet ports.

B. Ethernet switches shall meet the following requirements:

Property	**Specification**
Operating Temperature Range	-40 to 75°C
Operating Humidity	5% to 95%
Mounting	DIN-Rail
Media Access Control Addresses	8000
Aging Time	Programmable
Latency Typical	2.6 µs
Switching Method	Store-and-Forward
Redundant Input Voltage	10-30 VDC (Regulated)
Input Current	620 mA (Max.) at 24 VDC
10/100BaseTX Connectors	Fourteen (14) RJ-45 Copper Ports
100BaseFX Connectors	Two (2) SC Fiber Duplex Ports
10BaseT	> Cat3 Cable
100BaseTX	> Cat5 Cable
100BaseFX Multimode	50-62.5/125 micron
100BaseFXE Singlemode	7-10/125 micron

C. Ethernet switches shall be provided with two (2) single-mode or multi-mode fiber optic ports and shall be Model 716FXE2-SC-YY (single-mode) or Model 716FX2-SC (multi-mode), as manufactured by N-TRON, no substitutes.

D. Power supplies for Ethernet switches shall be Model NTPS-24-1.3 (1.3A at 24 VDC), as manufactured by N-TRON, no substitutes.

2.05 FLEXIBLE FABRIC INNERDUCT

A. The innerduct system shall be designed for fiber optic cabling and telecommunications.

B. The innerduct shall be flexible, nonmetallic tubing for insertion into a rigid conduit system to provide a smooth, low-friction path through the conduit for fiber optic cabling.

C. Innerduct shall be constructed of precision extruded nylon resin textile. Innerduct shall meet UL2024A for flame propagation and smoke density values for general applications.

D. Unless specified otherwise, one 3-cell innerduct pack shall be provided for 2", 3", and 4" conduit sizes. The multi-cell innerduct size shall match the conduit size shown on the Drawings.

E. Innerduct cells shall be pre-lubricated and preloaded with 1250-lb polyester flat woven pull tapes. Pull tapes shall be color coded and imprinted with accurate sequential footage marks.

F. Innerduct shall be provided with installation kits furnished by innerduct manufacturer. As a minimum, installation kits shall include 2500-lb swivels, chain harnesses, and pulling lubricant. The number of pulling swivels and chain harnesses shall be per the manufacturer's recommendations.

G. The flexible fabric innerduct system shall be as manufactured by MaxCell, or equal.

2.06 ANCILLARY MATERIALS AND COMPONENTS

A. Fiber Optic Splices

Fiber optic splices shall be the fusion type or mechanical type with a maximum insertion loss of 0.10 dB per splice. Splices shall be installed in splice trays specifically designed for the type of splice being used. The splice trays shall be suitable for use with loose tube cables.

B. Fiber Optic Splice Enclosures

Where permitted by the District, fiber optic splices shall be installed in a re-enterable, dustproof and waterproof splice enclosures. Splice enclosures shall be provided with removable splice trays suitable for holding a minimum of one full fiber turn and designed to protect individual fibers from excessive bending (macro and micro bending stresses). All splices shall be protected with a thermal shrink sleeve. Splice enclosures shall be as manufactured by Corning Optical Communications, Siecor, AT&T, or equal.

C. Fiber Optic Cable Pull Boxes

Fiber optic cable pull boxes shall be precast concrete pull boxes with galvanized steel diamond plate covers design for H-20 vehicle loading. Unless indicated otherwise on the Drawings, pull boxes shall be a minimum 32" wide x 42" long x 42" deep. Covers shall be hinged type with spring assist and shall be provided with "EMWD COMCBL" bead cast on the upper surface prior to hot dip galvanizing. Covers and frames shall be equipped with perimeter bolts to provide secure closure. Precast knockouts in the walls shall permit underground conduit penetrations. Hot dipped galvanized strut channel inserts, 1-5/8" square x 2' long, shall be embedded on each side of the interior of the pull box for attachment of the cable supports. Accessories shall include pulling eyes, precast concrete bottom with minimum 6" diameter floor drain grate and ground rod hole.

D. Supports

The fiber optic cable shall be supported on porcelain saddles attached to 1-5/8" hot dipped galvanized strut channel on the inside of the fiber optic pull boxes. The cable shall be secured to the porcelain saddles with cable tie wraps.

E. Duct Plugs

Duct plugs shall be designed to seal empty and utilized conduit/cable systems. Duct plugs shall be constructed of corrosion-proof materials. Duct plugs shall be removable and re-useable. Duct plugs for empty conduits shall be blank type. Duct plugs for conduit with fiber optic cabling shall contain the cable holes to match the cable sizes/numbers specified on the Drawings. Duct plugs shall be selected for the actual inside diameter of the conduit and outside diameter of the fiber optic cable(s). Duct plugs shall be Jackmoon as manufactured by Tyco Electronics, or equal.

F. Marker Tape

Marker tape shall be 3" wide and magnetically detectable with a solid aluminum foil core and polyethylene jacket resistant to alkalis, acids, and other destructive elements. Marker tape shall be continuously imprinted with "CAUTION: FIBER OPTIC CABLE". Marker tape background color shall be safety orange and caution text shall be black. Marker tape shall be as manufactured by Seton, or equal.

G. Locator Wire

Locator wire shall be 14-1 solid insulated copper wire, Type UF, in a continuous strand (no splices).

PART 3 - EXECUTION

3.01 CONDUIT

A. General

1. Conduit for fiber optic cabling shall be as shown on the Drawings and specified in Section 16050, Basic Electrical Materials and Methods. Conduit shall be installed in accordance with Section 16050, except as modified hereinafter.

2. The minimum bending radius of conduit shall be 3 feet.

3. Provide two (2) 45-degree (maximum) bends spaced a minimum of 2 feet apart in order to change direction.

4. Install conduit vertical elbows more than 36" deep for conduit risers to exit floor perpendicular to floor surface.

5. Install 1/4" minimum flat pull tape (1,250 lb minimum tensile strength) with imprinted length measurements in all spare conduits. Anchor each end of pull tape to prevent inadvertent pullback into conduit. Cap all conduits with removable caps.

6. Following the completion of conduit trench backfill and compaction, all conduits shall be cleared of loose material by brush and compressed air.

7. All conduits shall be tested to detect alignment or deformation problems by pulling a mandrel through the entire length of the conduit. The test mandrel shall be a minimum of 90% of the inside diameter of the conduit. The test mandrel shall be passed in both directions. This test shall be witnessed by the Inspector prior to pulling the innerduct and fiber optic cabling. Portions of the conduit which do not allow passage of the mandrel shall be removed and replaced with new conduit, and re-tested.

8. Contractor shall perform these same cleaning and testing procedures for existing conduits that are to be reused.

B. Conduit Installation Along Pipelines

1. Where indicated on the Drawings, fiber optic conduit shall be installed parallel with a pipeline and in the same trench as the pipeline.

2. Conduits shall be installed on one side of the pipeline trench, at least 2" and not more than 12" from the trench wall, at a depth of 3 to 4 feet below grade along the entire pipeline route. The conduit shall not cross over the pipe.

3. For conduits installed with a pipeline, conduits shall clear concrete structures and vaults associated with the pipeline by a minimum of one foot.

4. For pipelines installed in a casing (e.g. bore and jack sections of a pipeline alignment), conduit shall be installed in the annular space between the carrier pipe and the casing.

C. Locator Wire and Marker Tape

1. All buried fiber optic conduit shall be installed with a locator wire and detectable marker tape.

2. Locator wire shall be placed on top of the conduit and secured with tape. Locator wire shall be brought to the surface at maximum intervals of 660 feet in a precast concrete valve box. Contractor shall furnish and install valve box for the locator wire in accordance with District Standard Drawing B-656. Valve box cast iron cover shall be marked "EMWD: Respective Pipeline Service" (e.g. WATER, SEWER, OR RECLAIMED). Locator wire inside valve box shall be provided with a stainless steel tag labeled "FIBER OPTIC LOCATOR STATION". Valve box locations shall be confirmed in the field with the District's Inspector. Each Fiber Optic Locator Station shall be provided with an abovegrade marker post per District Standard Drawing B-665.

3. In addition to the locator wire, Contractor shall furnish and install detectable marker tape above the buried conduit. Marker tape shall be installed along the entire length of the conduit route at a depth of 12" to 18" below grade.

4. After all trench backfill operations are complete, Contractor shall perform a locatability test of all conduit locator wire to confirm that the wire is continuous. Contractor shall be responsible for all costs to confirm, locate, and repair any breaks in the location wire identified in the locatability test.

3.02 PULL BOXES

A. The Drawings diagrammatically indicate the desired location of pull boxes, conduit runs, and other fiber optic system items. Exact locations shall be determined by the Contractor based on physical size and arrangement of equipment, finished elevations, calculated cable pulling tensions, field obstructions, and criteria below. Locations shown on the Drawings should be followed as closely as possible; however, pull boxes shall be located according to the following criteria:

1. At no point shall the cable pulling tension exceed 600 pounds. If cable pulling tension is calculated to exceed 600 pounds, additional pull boxes shall be provided at no extra cost to the District.

2. The maximum distance between any two pull boxes shall not exceed 1,200 feet.

3. Within the 1,200-foot distance, the Contractor shall install pull boxes at locations wherever the cumulative change of direction of the conduit exceeds 180 degrees.

4. The minimum bending radius for conduit shall be 3 feet.

5. A pull box shall be installed on one side of each bore and jack crossing. However, for any crossing which requires multiple casings and more than 180 degrees of conduit bends to account for elevation differences or route adjustments, a pullbox shall be provided on both sides of the crossing.

6. Pull boxes shall be installed a minimum of 12" from all structures.

7. Where fiber optic conduit is installed parallel with a pipeline, pull boxes shall be installed 3 feet from the pipeline (clear horizontal distance), unless indicated otherwise on the Drawings.

B. Pull boxes located in paved areas shall be installed so that the top of the cover is flush with the pavement. Pull boxes located in dirt roads shall be set flush with the finished grade and a 10-foot square asphalt concrete paved section shall be constructed around the pull box in accordance with District Standard Drawing SA-47. Pull boxes located outside of the traveled way shall be set 4" higher than the final grade of the restored surface to prevent accumulation of dirt, silt and debris on the top of the cover.

C. Contractor shall perform conduit integrity tests for each section between the pull boxes after backfilling and compaction using the test and procedures described in this Section. These tests shall be performed prior to installation of the innerduct and fiber optic cabling.

D. Any voids around conduit entries into pull boxes shall be filled with concrete grout to prevent the intrusion of debris and water into the pull boxes. In addition, any pull box knock-out with a conduit shall be filled with concrete grout. All concrete grout fill shall be finished flush with the interior surface of the pull box wall.

E. Pull box conduit entries shall be sealed with duct plugs, as specified herein, to prevent the intrusion of water and debris into the pull boxes.

F. Pull boxes shall be installed on a compacted level foundation consisting of 8" of gravel fill complying with Section 02201. The subgrade beneath the gravel fill shall be scarified to a depth of 12" and compacted to 90% (minimum) relative compaction. Compaction around pull boxes and associated components shall be performed in accordance with Section 02201.

G. Unless specified otherwise, a 3/4" x 10' long ground rod shall be provided in each pull box along with a grounding clamp and #4 AWG bare copper ground wire.

H. Upon final acceptance of the conduit system all pull boxes shall be free of debris and water, and be ready for innerduct and fiber optic cable installation.

I. The pulling of fiber optic cable shall be hand assisted at each pull box. The cable shall not be crushed, kinked or forced around a sharp corner. Sufficient slack shall be left at each end of the cable to allow proper cable termination.

J. The cable shall be looped in each pull box to provide approximately 15 feet of extra cable. At termination points, such as at patch panels and cabinets, a 15-foot loop of cable shall also be provided wherever space permits. The fiber optic cable shall be coiled and secured with cable ties to pull box rack arms. Contractor shall ensure that the minimum bending radius of the fiber optic cable is not compromised when preparing and securing the stored cable slack.

K. When all cables at each pull box are installed and securely racked, all void areas around conduit containing cables shall be sealed with duct plugs, as specified herein. In addition, blank duct plugs shall be installed in all spare conduits.

L. Imprinted plastic coated cloth identification and warning tags shall be securely attached to the cables in at least 2 locations in each pull box. Tags shall be as manufactured by Thomas & Betts, or Brady.

M. At each pull box, a plastic warning placard shall be attached to the interior of the pull box with stainless steel anchors and fender washers. The placard shall be provided with a safety orange background and black letter stating, "CAUTION: FIBER OPTIC CABLE".

3.03 INNERDUCT

A. Unless indicated otherwise on the Drawings, flexible fabric innerduct shall be installed in all conduit. Innerduct shall be installed in accordance with the manufacturer's written instructions.

B. Innerduct shall be installed in continuous, un-spliced lengths between pull boxes and/or termination points.

C. Provide suitable slack in pull boxes and at turns to ensure that the innerduct will be installed un-kinked and free.

3.04 FIBER OPTIC CABLING

A. Unless indicated otherwise on the Drawings, fiber optic cabling shall be installed in conduit, inside flexible fabric innerduct.

B. Contractor shall install fiber optic cabling in accordance with the approved cable routing plan, patch panel location plan, and pull box plan.

C. Fiber optic cabling shall be installed in accordance with innerduct and cable manufacturer's printed instructions, telecommunication industry standards, and all applicable state and federal codes. Contractor shall determine a suitable cable installation method to ensure that all cable installation requirements are met in all conduit sections.

Fiber optic system components shall be installed in accordance with the manufacturer's printed instructions.

D. The requirements specified herein are provided to ensure the integrity of the fiber optic cable system, and represent minimum installation requirements. Additional measures not specified herein shall be taken during installation if recommended by the manufacturer or required to ensure protection of the cable.

E. All work shall be performed in conformance with the highest standards of quality and craftsmanship in the telecommunication industry with regard to the electrical and mechanical integrity of the installation (including all connections), the finished appearance of the installation, and the accuracy and completeness of the documentation.

F. Fiber optic cable shall be installed in continuous lengths without intermediate splices, except where approved by the District.

G. Field personnel shall be formally trained in all aspects of cable installation techniques and procedures, and shall be certified by the cable manufacturer.

H. Special care and precautions shall be exercised during cable installation to ensure that cable tensile limits and bending limits are not exceeded under any circumstances.

I. Whenever power equipment is utilized to install fiber optic cable, the pulling speed shall not exceed 30 meters per second, and commercial dynamometers or load-cell instruments shall be provided to continuously monitor cable pulling tension. Equipment shall be designed to prevent a preset pulling tension from being exceeded. The fiber optic cable manufacturer shall provide the pulling tension set point. If excessive pulling tension is detected, all cable pulling operations shall immediately cease and the District shall be notified.

All cable pulls shall be documented by a graph of pulling tension versus distance, which shall be annotated with the following information:

1. Cable reel number

2. Date and time of pull

3. Location of pull point and conduit route per routing plan

4. Explanations of any abnormalities in readings or interruptions

5. Name of installation supervisor.

Cable pull graphs shall be submitted to the District for review and approval prior to commencing installation of cable terminations.

J. Large diameter wheels, pulling sheaves, cable guides, swivels, and grips shall be used to maintain the appropriate cable bend radius and to prevent cable twist.

K. A cable feeder guide shall be utilized between the cable reel and the face of the conduit to protect the cable and guide it off the reel and into the conduit. The cable shall be carefully inspected for jacket defects as it is removed from the cable reel. If defects are observed, the pulling operation shall be terminated immediately and the District shall be notified.

L. As the cable is pulled off the reel and into the cable feeder guide, it shall be lubricated with a water-based type lubricant approved by the cable manufacturer and the innerduct manufacturer.

M. During installation, the cable shall not be kinked as it comes off the spool. Crushed or kinked cable shall be replaced with new cable

N. No vehicular or pedestrian traffic shall be allowed to run over fiber optic cables. During installation, the fiber optic cables shall not be left exposed or unattended

O. Crushed or kinked cable shall be replaced with new cable. In addition, repair of cable jackets will not be permitted. Jacket damage shall require removal and re-installation of a new cable at no cost to the District.

P. Cables shall not be left in tension stress after installation.

3.05 SPLICING

A. Fiber optic cable splices will only be permitted on a case-by-case basis, and only after the Contractor has demonstrated to the District's satisfaction, that fiber optic cable manufacturers are unable to manufacturer the specified cables in lengths that would allow installation without splices.

B. When splicing is authorized by the District, splicing shall be by trained, authorized persons only. Any allowed splicing of fiber optic cable shall be by fusion splice only, no mechanical splices will be permitted.

C. All fusion splicing equipment shall be in good working order, properly calibrated, and meeting all industry standards and safety regulations. Cable preparation, closure installation and splicing shall be accomplished in accordance with the manufacturer's recommendations and approved industry standards.

D. Splices shall be made in re-enterable, dustproof, and waterproof splice enclosures as specified herein. All splices shall be protected with a thermal shrink sleeve.

E. The average splice loss shall be no greater than 0.1 dB per splice. The average splice loss is defined as the summation of the loss as measured in both directions using an optical time domain reflectometer (OTDR) through the fusion splice, divided by two. No individual splice loss measured in a single direction shall exceed 0.15 dB.

F. Unless indicated otherwise on the Drawings, provide a minimum of 15 feet of fiber optic cable looped adjacent to the splice enclosure.

3.06 TERMINATIONS

A. Unless specified otherwise, fiber optic cable shall be terminated inside a patch panel. Direct landing of cable fibers to a router, switch, or PLC will not be permitted.

B. Connections to cable fibers at patch panels shall be performed by fusion splicing of fiber optic patch cords (jumpers). Patch cords shall be tight-buffered, riser rated and equipped with ST connectors.

C. All cable terminations shall be provided with permanent labels. Labels shall be pressure sensitive polyester imprinted with smear resistant ink.

3.07 MANUFACTURER FIELD SERVICES

Contractor shall furnish the services of certified manufacturer engineering representatives for the material and equipment specified herein at the project site(s) to provide the following:

A. Assistance and inspection during installation of the fiber optic system. Upon completion of installation, manufacturers shall provide certificates of proper installation for all fiber optic system components.

B. Assistance, troubleshooting, and witnessing of system testing.

C. Operation and maintenance training of District personnel. Operation and maintenance training shall include all aspects of operating and maintaining the fiber optic system, including, but not limited to: safety procedures, troubleshooting, preventative maintenance, performing connections to spare fibers, and testing. Unless specified otherwise, 8 hours (total) of training shall be provided. All training shall be coordinated with the District, and at least 2 weeks advance notice shall be provided for scheduling the training sessions.

3.08 FIELD TESTS

A. Contractor shall perform and document the testing of the fiber optic system, including all cables, patch panels, patch cords, connectors, and splices as specified herein. All field testing will be witnessed by the District. Contractor shall coordinate all field testing activities with the District and provide a minimum of 2 weeks advance notice prior to commencing the testing.

B. The purpose of the testing is to verify that the fiber cable system is free from defects and that the attenuation of the optical fibers and associated components are within the performance values specified herein and to provide a baseline for comparison purposes.

C. A recording optical time domain refractometer (OTDR) shall be utilized to test the fiber optic system. The ODTR shall be equipped with an X-Y plotter to provide a hard copy record of each test measurement. In addition, the OTDR shall be equipped with a light source for testing single mode and multimode fibers. The OTDR shall be calibrated for the correct index of refraction to provide proper length measurement for the known length of reference fiber. The OTDR shall be capable of providing sufficient internal masking to allow an entire cable section to be tested. Optical fiber jumpers of sufficient length shall be provided to display the required cable section.

D. After installation of all fiber optic cable, patch panels, patch cords, and connectors is complete, the following tests shall be performed:

1. The end-to-end continuity and attenuation of each optical fiber shall be tested using the OTDR. All traces shall display the entire length of the cable under test, highlighting any localized loss discontinuities, including installation induced losses and connector losses. The pulse width of the OTDR shall be set at a sufficient width to provide adequate injected power to measure the entire length of the fiber under test.

2. A transmission test shall be performed with the use of stabilized light sources and power meters. Single mode fibers shall be tested with 1310 and 1550 Nm light wavelengths, and multimode fibers shall be tested with 850 and 1300 Nm light wavelengths. The testing shall be conducted in both directions on each fiber of each cable.

3. If connectors and/or splices exist in the cable being tested, then two traces shall be recorded. One trace shall record the fiber loss (dB) and average attenuation (dB/km) of the entire cable segment under test, including connectors and splices. The second trace shall display a magnified view of the connector and splice regions, providing the connector and splice losses (dB).

4. Hard copies and electronic copies of all test documentation shall be submitted to the District along with any special computer software required for viewing the OTDR traces. Provide test documentation that includes the cable and fiber number tested, total length of fiber (km), fiber loss (dB), and average fiber attenuation (in dB/km). Each OTDR trace plot shall also include the following information:

    a. Date and time of the test
    b. Cable identification number
    c. Cable segment identification number
    d. Fiber color or sub-cable number
    e. Launch point connector number
    f. Optical wavelength used for the test
    g. Refractive index setting of the OTDR
    h. Pulse width setting of the OTDR
    i. Averaging interval of the test

5. Contractor shall compare the test results to the performance requirements specified herein. If the field test results exceed the specified performance requirements, the cable and associated components shall be removed and replaced with a new cable and components, and then re-tested, all at no additional cost to the District.

E. Upon completion of field testing all fiber optic cable and cords shall be secured, and any spare connectors shall be provided with end caps to protect the connectors from dust.

3.09 RECORD INFORMATION

Upon satisfactory completion of all fiber optic system installation, Contractor shall provide the District with one set of cable routing plans showing the "as-built" locations of all pull boxes, junction boxes, and patch panels.

END OF SECTION 16890